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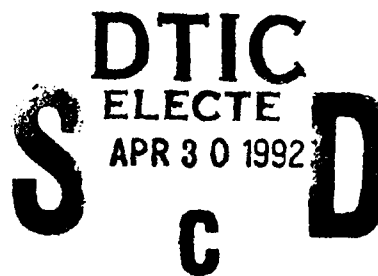||||||||||||||||||||||||||

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FINAL TECHNICAL REPORT

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Research Conducted by

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for the

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13. ABSTRACT (Maximum 200 words)

This report describes the results of a modification to the University of Massachusett's 95 GHz polarimetric radar. This modification was done to reduce problems caused by phase noise originating from the radar's millimeter-wave oscillator

14. SUBJECT TERMS

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Millimeter-wave   Scattering matrix

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1. Forward

The Microwave Remote Sensing Laboratory at the University of Massachusetts has developed a 95 GHz coherent polarimeter. This instrument measures a target's polarimetric scattering matrix. Such a measurement is susceptible to corruption from phase noise originating from the radar's millimeter-wave source. This report describes the effects of this problem, and also the steps taken to correct it.

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2. List of Appendices

Not Applicable

3. Body of Report

A. Statement of Problem

Phase (or FM) noise is a short term phase variation of a signal. It can be modeled using a randomly varying vector on the tip of a carrier's phasor (Figure 1). One effect of this vector is to change the phase of the resultant sum vector. Rotation of the noise vector during the delay time between pulse transmission and reception adds a phase error to the measurement of the scattered field.
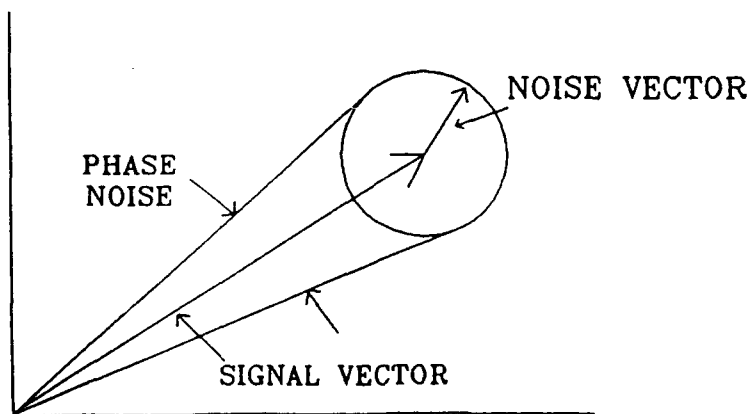

Figure 1

Vector model of phase noise

For a given range or time delay, higher levels of noise power far away from the carrier cause more phase noise than similar levels close to the carrier. This is because frequencies farther removed from the carrier allow for a faster rotation of the noise vector in Figure 1. Quantitatively, this relationship can be analyzed by modeling phase noise as FM sideband signals about a carrier frequency [Goldman, 1989]. The ratio of sideband power to carrier power of a FM signal is

$$\frac{P_{SB}}{P_{CAR}} \cong [J_1(\eta)]^2 \tag{1}$$

where

$$P_{SB} \quad \triangleq \quad \text{sideband power}$$

$$P_{CAR} \quad \triangleq \quad \text{carrier power}$$

$$J_1 \quad \triangleq \quad \text{Bessel function of order 1}$$

$$\eta = \frac{f_d}{f_m} \quad \triangleq \quad \text{modulation index}$$

$$f_d \quad \triangleq \quad \text{frequency deviation from carrier}$$

$$f_m \quad \triangleq \quad \text{frequency of modulation}$$

By using a Taylor expansion for the Bessel function, (1) can be rewritten:

$$\frac{P_{SB}}{P_{CAR}} = \frac{\eta^2}{4} \tag{2a}$$

In logarithmic notation, this can be written

$$\mathcal{L} = 10\log(\eta^2) - 6dB \tag{2b}$$

where $\mathcal{L}$ is the single sideband phase noise in a 1 Hz bandwidth in decibels below the carrier power (dBc/Hz).

The effect of a time delay upon the phase noise spectrum is also important. Analysis is accomplished with the use of a *delay function*, $K^2(f_m, \tau)$, which effectively modifies the

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modulation index [1]:

$$\eta_{eff} = \eta\sqrt{K^2(f_m,\tau)} \tag{3}$$

where

$$K^2(f_m,\tau) = 2[1 - \cos(2\pi f_m\tau)]$$

$$\tau \stackrel{\Delta}{=} \text{ time delay, and}$$

$$f_m \stackrel{\Delta}{=} \text{ offset from carrier.}$$

The phase noise resulting from mixing a signal with a delayed version of itself can then be written as

$$\mathcal{L}_\tau = 10\log\left[\frac{\eta^2}{4}K^2(f_m,\tau)\right] \quad (\text{dBc/Hz}) \tag{4}$$

The RMS phase noise is obtained by integrating this function from the carrier frequency, f_c, to the edge of the receiver's bandwidth, f_{BW}:

$$\phi_{RMS} = \int_{f_c}^{f_{BW}} \mathcal{L}_T(f_m,\tau)df_m \tag{5}$$

Phase noise affects some important measurements in the 95 GHz polarimeter. The scattering matrix, $[S]$, is measured with two transmit pulses with this radar. Reciprocity demands that the off–diagonal terms of $[S]$, S_{VH} and S_{HV}, be equivalent. However, phase noise of the measurements of S_{VH} and S_{HV} can corrupt this. Doppler measurements are also affected, since phase errors are interpreted as erratic movement of the target.

The most significant source of phase noise in the system is the millimeter–wave local oscillator. This consists of a Gunn diode oscillator that is locked to a stable 120 MHz reference oscillator by a phase locked loop, as shown in Figure 2. The bias voltage is applied to the Gunn oscillator by the lock box, which forces the oscillator to remain locked to a harmonic of the reference signal.

A plot of measured phase noise versus range for a stable corner reflector is shown in Figure 3. An RMS phase error of 6° at 200 meters is unacceptable for the type of measurements that this radar has to perform.
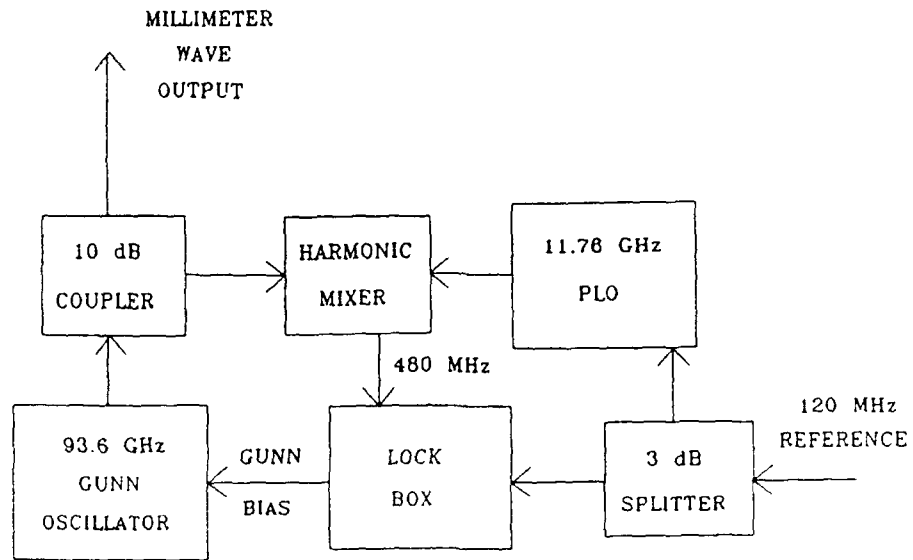
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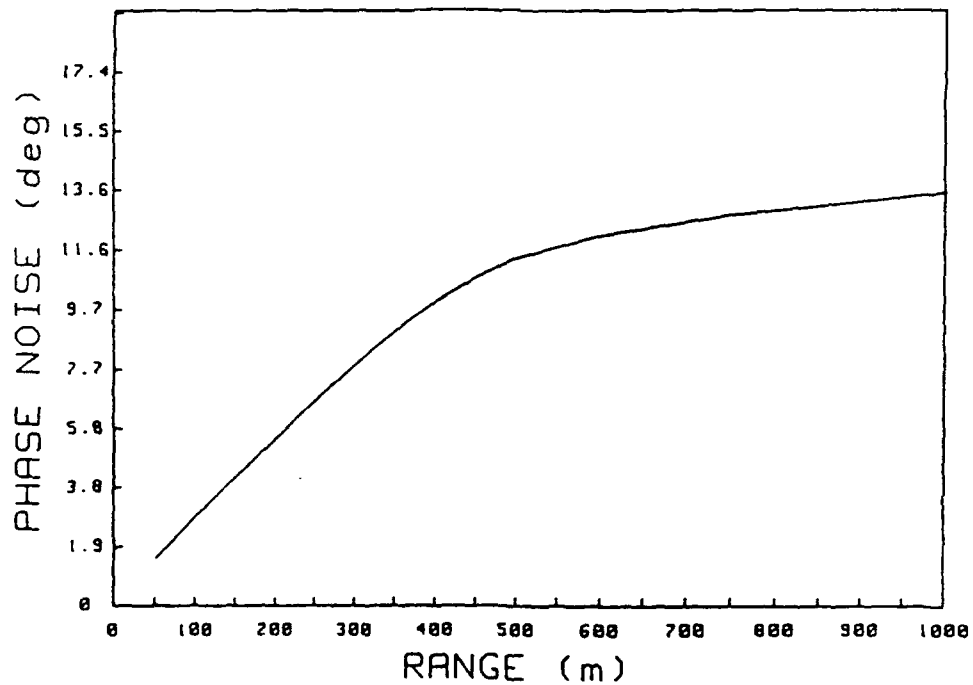Figure 2

Millimeter-wave phase locked oscillator

Figure 3

Phase noise versus range - original source

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B. Results

After researching the options to reduce the rms phase noise of the MIRSL 95 GHz radar, we decided that acquisition of a source module from the Hughes Aircraft Company would greatly improve the situation. The Hughes source is similar in concept to the original millimeter-wave source, except that it has an analog phase lock loop circuit. It also has an integral VHF reference with lower phase noise. These features contribute to a better phase noise specification, and a decreased phase noise performance (Figure 4) when it is used as a radar source oscillator. Since this source does not operate at the frequency of 93.6 GHz of the two-antenna W-Band radar originally funded by the ARO, it was installed on a single antenna W-Band system being developed for the U.S. Department of Energy. This radar is currently undergoing engineering tests with field operation scheduled for January 1992. Unlike the existing polarimeter, it is a single antenna design. The ARO funded radar is currently operating with a multiplied source obtained from MIRSL's HP 8510B Network Analyzer. Polarimetric measurements of snow by both radars are planned for the 1991-92 winter season.
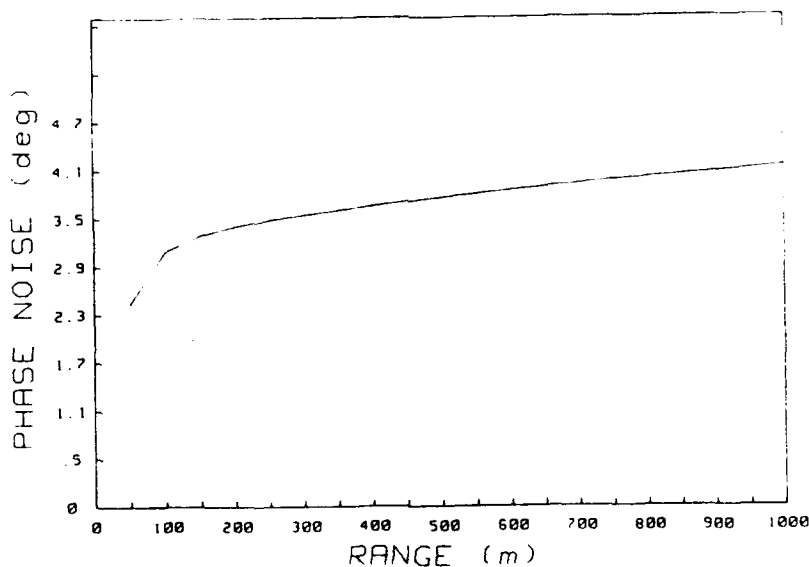

Figure 4

Phase noise versus range - Hughes source

C. List of Publications/Theses

Not Applicable

D. Participating Personnel

    Philip Langlois

    Paul Chang

4. Bibliography

[1.] Goldman, S.J., 1989: Phase Noise Analysis in Radar Systems using Personal Computers, John Wiley & Sons, New York

5. Appendices

    Not Applicable